CP- and *CPT*-Violation Measurements in *B* Decays at Belle

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Contents

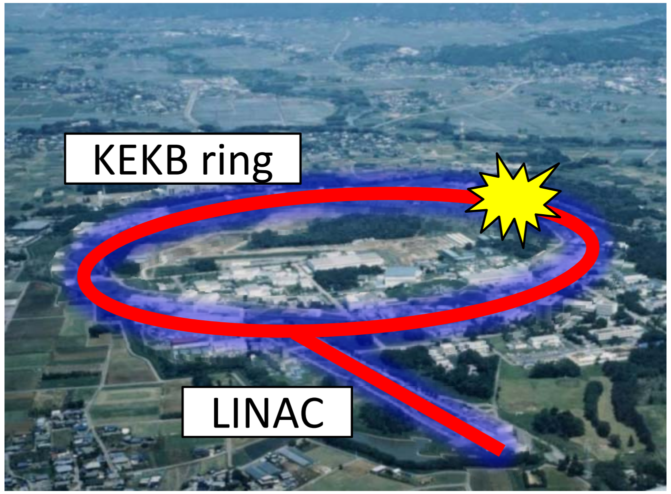
- **Introduction**

- **Very new *CP*- and *CPT*-violation measurements at Belle**
  - *CP* violation in $B^0 \to (c\bar{c})K^0$ ← ***Latest***
  - Branching fraction of $B^0 \to D^+D^-$ and *CP* violation ← ***New!***
  - Branching fraction of $B^0 \to D^{*+}D^{*-}$ and *CP* violation ← ***New!***
  - *CPT* violation in $B^0 \to J/\psi K^0$, $D^{(*)-}h^+$, and $D^{*-}\ell^+\nu_\ell$ ← ***New!***

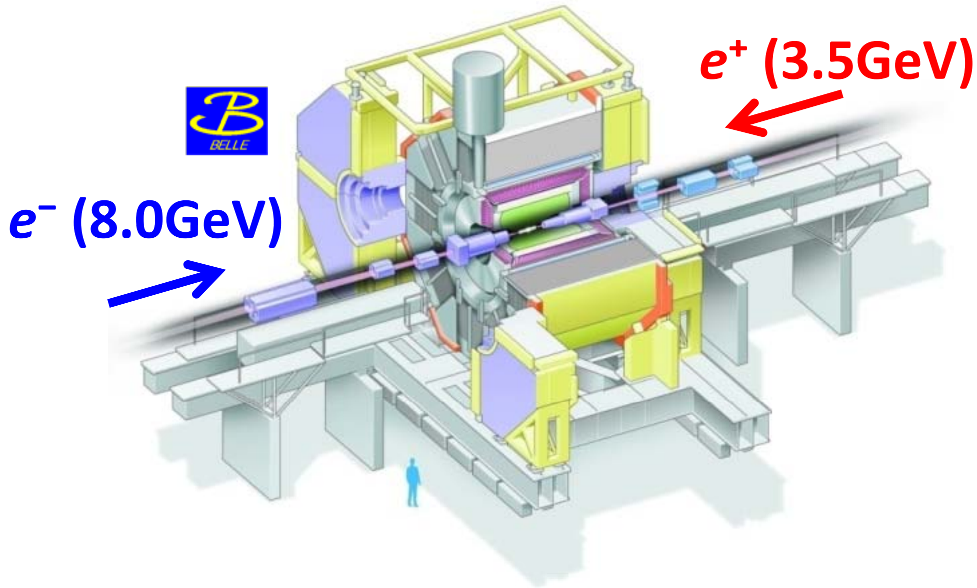
- **Summary**

One-Page Summary of KEK B-Factory

- **KEKB accelerator**
  - 8.0 GeV e^- x 3.5 GeV e^+ collider to produce pairs of $B\bar{B}$ mesons.
  - 3km in circumference.



- **Belle detector**
  - Complex of vertex detector, drift chamber, PID detectors, and EM calorimeter.



Completed data taking on Jun.30th, 2010 to start SuperKEKB/Belle II upgrade.
Total recorded luminosity = 1052.79 fb^{-1}.
# of Υ(4*S*)→*BB* is 772x10^6.

Manifestation of *CP* Violation

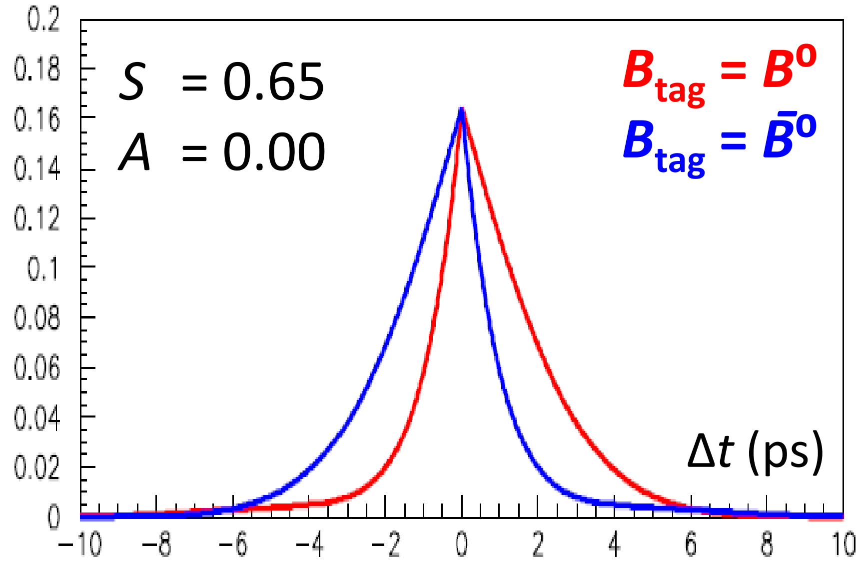
$$e^{+}e^{-} \rightarrow \Upsilon(4S) \rightarrow B\overline{B}$$

The e^+-e^- collision produces a pair of *B* mesons through Υ(4*S*).

Mixing-induced CPV manifests itself in a signed time duration "$\Delta t = t_{BCP} - t_{Btag}$", and a *B*-meson flavor *q*, where

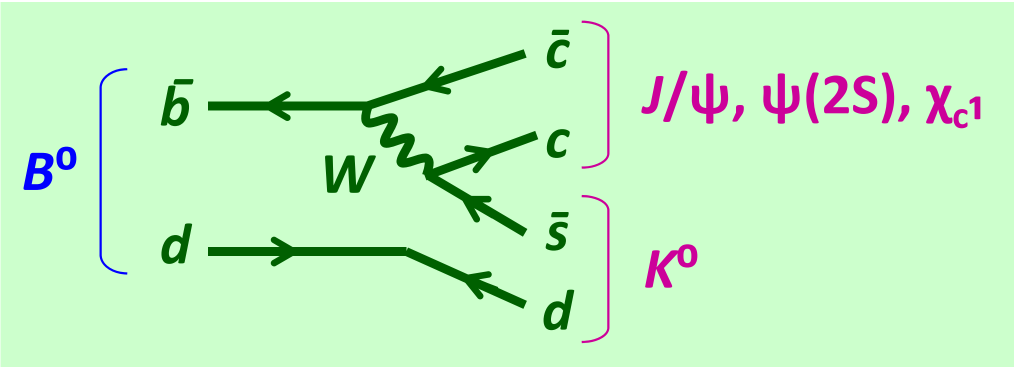
- t_{BCP} … time when one *B* decays to the *CP* eigenstate.
- t_{Btag} … time when the other *B* decays to the flavor-specific state.
- q … +1 for $B_{tag}=B^0$ and –1 for $B_{tag}=\bar{B}^0$.

$$P_{sig}(\Delta t, q; S, A) = \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B}\left[1 \pm q \cdot (A \cos \Delta m_d \Delta t + S \sin \Delta m_d \Delta t)\right]$$

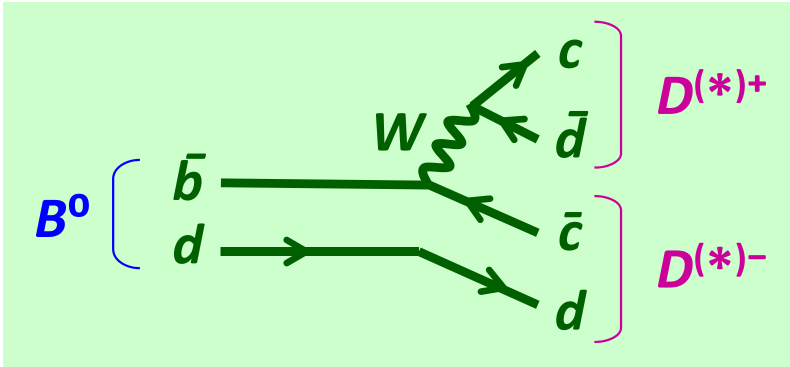


CPV in $B^0 \to (c\bar{c})K^0$ and $D^{(*)+}D^{(*)-}$ Decays

- $B^0 \to (c\bar{c})K^0$
  ($b \to c\bar{c}s$ tree transition)



- $B^0 \to D^{(*)+}D^{(*)-}$
  ($b \to c\bar{c}d$ tree transition)



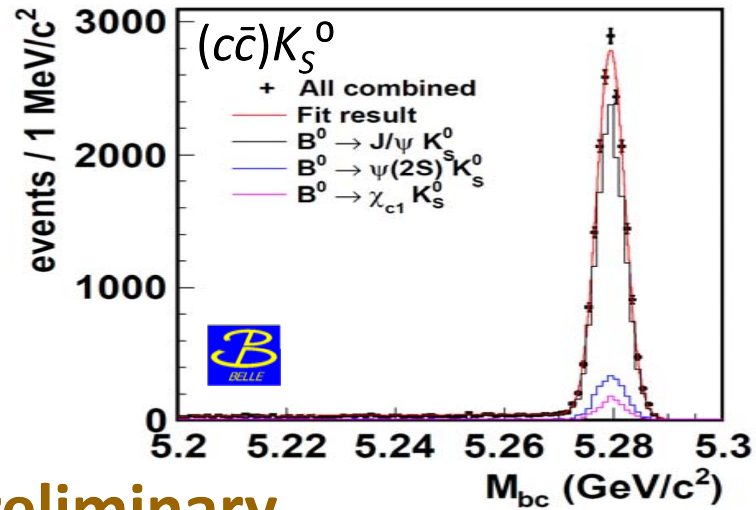
Both decays are mainly mediated by a tree diagram.
The diagrams include neither V_{ub} nor V_{td} → ϕ_1 is accessible.

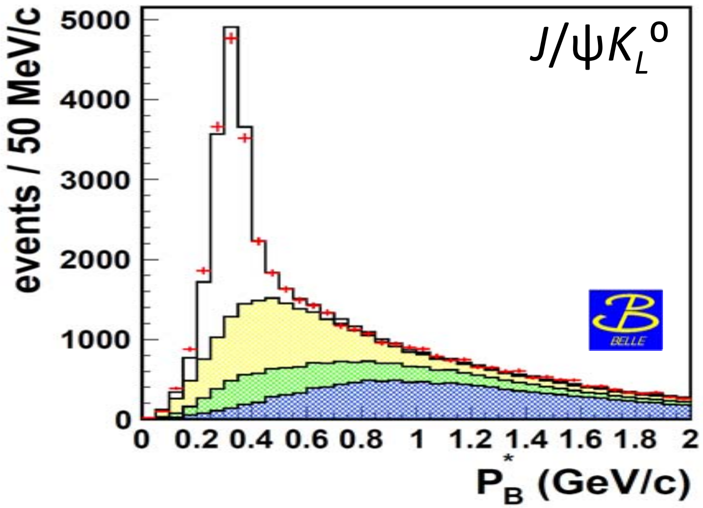
SM prediction: $S = -\eta_{CP}\sin 2\phi_1$, $A \approx 0$

$\eta_{CP} = \pm 1$ … *CP* eigenvalue of the final state.

$B^0 \to (c\bar{c})K^0$ Reconstruction

from 772 x 10^6 $B\bar{B}$ pairs = final Belle data sample





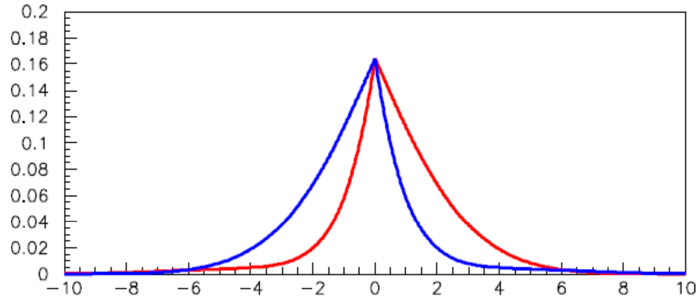
Belle preliminary

	$J/\psi K_S^0$	$J/\psi K_L^0$	$\psi(2S)K_S^0$	$\chi_{c1}K_S^0$	$N_{B\bar{B}}$ (x 10^6)
Signal yield	**12727±115**	**10087±154**	**1981±46**	**943±33**	**772**
Purity [%]	**97**	**63**	**93**	**89**	
Signal yield (ICHEP06)	7484±87	6512±123	–	–	535
Purity (ICHEP06) [%]	97	59	–	–	

K.-F. Chen *et al.*, Phys. Rev. Lett. **98**, 031802 (2007) for ICHEP06.

Improvement due to reprocessing with better tracking algorithm in addition to ~40% increase in $N_{B\bar{B}}$.

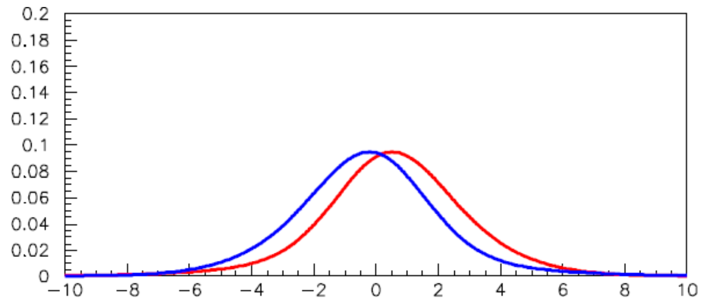
Extraction of *CP*-Violating Parameters



Bare Δ*t* distribution

$$P_{\mathrm{sig}}(\Delta t, q; S, A) = \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B}\left[1 \pm q\cdot(A\cos\Delta m_d \Delta t + S\sin\Delta m_d \Delta t)\right]$$

✓ Background contamination ✓ Δ*t* resolution ✓ Wrong flavor determination



Modified Δ*t* distribution

$$P(\Delta t, q; S, A) =$$

$$f_{\mathrm{sig}} \frac{e^{-|\Delta t|/\tau_B}}{4\tau_B}\left[1 \pm q(1-2w)(A\cos\Delta m_d \Delta t + S\sin\Delta m_d \Delta t)\right] \otimes R$$

$$+ (1 - f_{\mathrm{sig}}) P_{\mathrm{bkg}}(\Delta t)$$

wrong tag prob. (→ w)

Δ*t* reosl. (→ R)

background

- **Unbinned maximum likelihood fit**
  - Search for *S* and *A* that maximize $L(S, A) \equiv \prod_{i=1}^{\text{all events}} P(\Delta t_i, q_i; S, A)$

CPV in $B^0 \to (c\bar{c})K^0$

Belle preliminary

$$\sin 2\phi_1 = +0.668 \pm 0.023 \pm 0.013$$

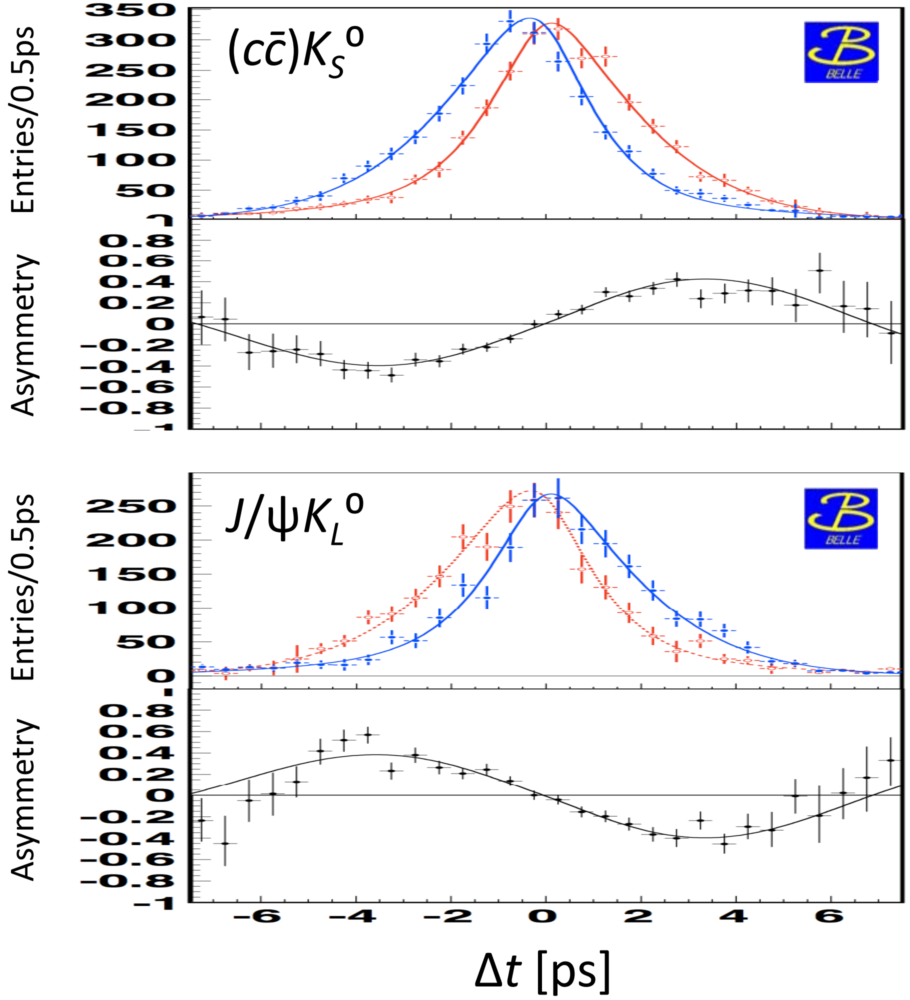
$$A = +0.007 \pm 0.016 \pm 0.013$$

772×10^6 $B\bar{B}$ pairs

$B^0 \to (cc)K_S^0$ + $B^0 \to J/\psi K_L^0$ combined

$B_{tag} = B^0$

$B_{tag} = \bar{B}^0$



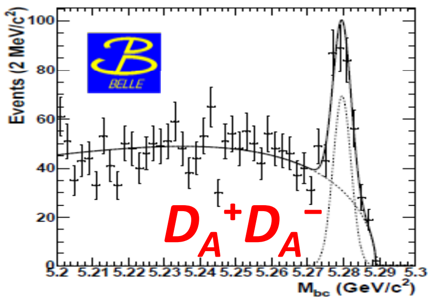
Sources of systematic errors

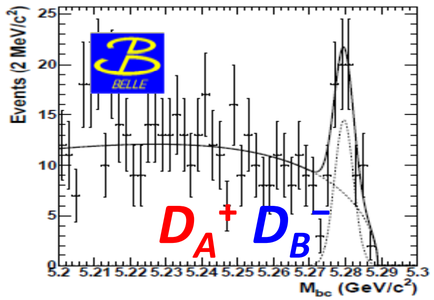
Category	δS	δA
Vertexing	$+0.008$ -0.009	± 0.008
Flavor tagging	$+0.004$ -0.003	± 0.003
Vertex resolution	± 0.007	± 0.001
Physics parameters	± 0.001	< 0.001
Fit bias	± 0.004	± 0.005
$J/\psi K_S^0$ signal fraction	± 0.002	± 0.001
$J/\psi K_L^0$ signal fraction	± 0.004	$+0.000$ -0.002
$\psi(2S)K_S^0$ signal fraction	< 0.001	< 0.001
$\chi_{c1}K_S^0$ signal fraction	< 0.001	< 0.001
Background Δt	± 0.002	± 0.001
Tag-side interference	± 0.001	± 0.008
Total	± 0.013	± 0.013

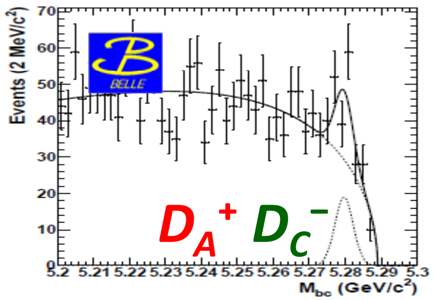
Branching Fraction of $B^0 \to D^+D^-$ *New!*

from 772 x 10^6 $B\bar{B}$ pairs = final Belle data sample

- ***B*^{0} reconstruction**
  - D^+ is reconstructed in one of $D_A^+ = K^-\pi^+\pi^+$, $D_B^+ = K_S^0\pi^+$, and $D_C^+ = K_S^0\pi^+\pi^0$.







N_{sig}=221.4±18.6, BF=(2.16±0.18)x10^{-4}

N_{sig}=48.0±8.9, BF=(1.96±0.36)x10^{-4}

N_{sig}=54.1±14.6, BF=(1.83±0.49)x10^{-4}

Belle preliminary

$$\mathrm{BF} = (2.09 \pm 0.15 \pm 0.18) \times 10^{-4}$$

Small contribution from $B^0 \to D^+K^{(*)0}\pi^-$ to peaking background is estimated by D^* mass sideband and subtracted.

Sources of systematic errors

Category	$\delta(BF)$
Tracking efficiency	2.0 %
K_S^0 recon. efficiency	1.0 %
π^0 recon. efficiency	0.5 %
K/π selection efficiency	5.4 %
D and K_S^0 BF	4.3 %
Number of $B\bar{B}$	1.4 %
Fit model	1.1 %
Event recon. efficiency	1.0%
$q\bar{q}$ continuum suppression	4.1 %
Total	8.6 %

Previous measurement (535x10^6 $B\bar{B}$ pairs):

$$BF = (1.97 \pm 0.20 \pm 0.20) \times 10^{-4}$$

S. Fratina *et al.*, Phys. Rev. Lett. **98**, 221802 (2007).

Efficiency increase is larger than $(c\bar{c})K^0$, because of larger track multiplicity in D^+D^-.

CPV in $B^0 \to D^+ D^-$ *New!*

"*CP* violation" in control sample: $B^0 \to D_s^+ D^-$

$$S = -0.09 \pm 0.06, \quad A = +0.02 \pm 0.04$$

consistent to zero.

Belle preliminary

$$S = -1.06 \pm 0.21 \pm 0.07$$

$$A = +0.43 \pm 0.17 \pm 0.04$$

772×10^6 $B\bar{B}$ pairs

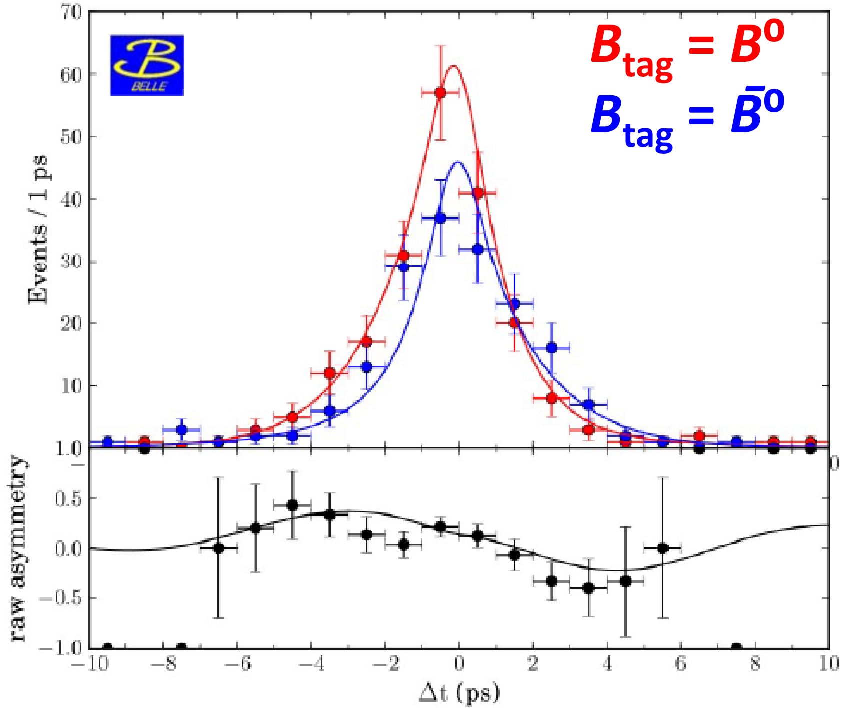
$B^0 \to (K^-\pi^+\pi^+)(K^+\pi^-\pi^-)$, $(K^-\pi^+\pi^+)(K_S\pi^0)$+c.c.

Previous measurement (535×10^6 $B\bar{B}$ pairs):

$$S = -1.13 \pm 0.37 \pm 0.09,$$

$$A = +0.91 \pm 0.23 \pm 0.06$$

Unexpectedly large *A* come closer to zero with more statistics.



Sources of systematic errors

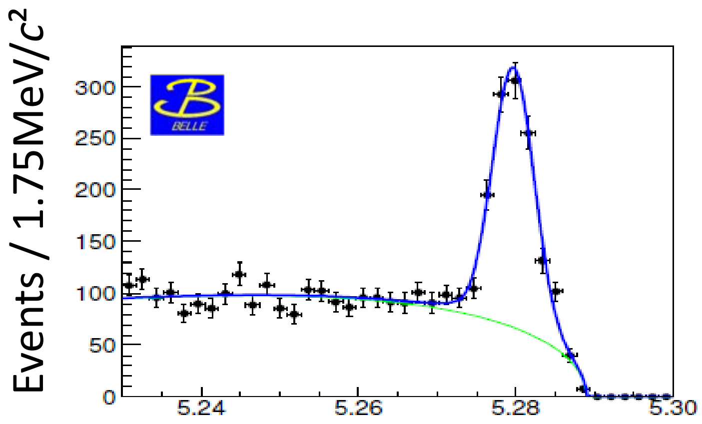
Category	δS	δA
Vertexing	±0.011	±0.006
Flavor tagging	±0.011	±0.017
Vertex resolution	±0.063	±0.022
Physics parameters	±0.007	±0.004
Signal fraction	±0.012	±0.019
Background Δt	±0.027	±0.006
Tag-side interference	±0.001	±0.008
Total	±0.072	±0.036

Branching Fraction of $B^0 \to D^{*+}D^{*-}$ *New!*

from 772 x 10^6 $B\bar{B}$ pairs = final Belle data sample

- **B^0 reconstruction**
  - B^0 is reconstructed in one of $(D^0\pi^+)(\bar{D}^0\pi^-)$, $(D^0\pi^+)(D^+\pi^0)$, c.c.
  - Employed sub-decays of D meson:

$D^0 \to K^-\pi^+(\pi^0)$, $D^0 \to K^-\pi^+\pi^+\pi^-$, $D^0 \to K_S^0\pi^+\pi^-$, $D^0 \to K^-K^+$
$D^+ \to K^-\pi^+\pi^+$, $D^+ \to K_S^0\pi^+(\pi^0)$, $D^+ \to K^-K^+\pi^+$



N_{sig}=1225±59 Mbc [GeV/c^2]

Belle preliminary

$$\mathrm{BF} = (7.82 \pm 0.38 \pm 0.60) \times 10^{-4}$$

Sources of systematic errors

Category	$\delta(BF)$	Category	$\delta(BF)$
Tracking efficiency	1.73 %	Number of $B\bar{B}$	1.40 %
K_S^0 recon. efficiency	0.79 %	Fit model	0.24 %
π^0 recon. efficiency	2.99 %	Event recon. efficiency	0.82%
K/π selection efficiency	5.02 %	Slow $\pi^{\pm}$ recon. efficiency	3.19 %
D^- and D^* BF	3.13 %		
Total			7.77 %

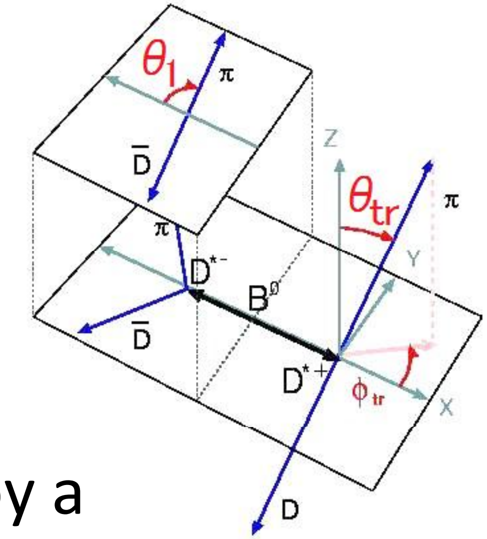
Previous measurement (657x10^6 $B\bar{B}$ pairs):

N_{sig}=553±30 K. Vervink *et al.*, Phys. Rev. D **80**, 111104(R) (2009).

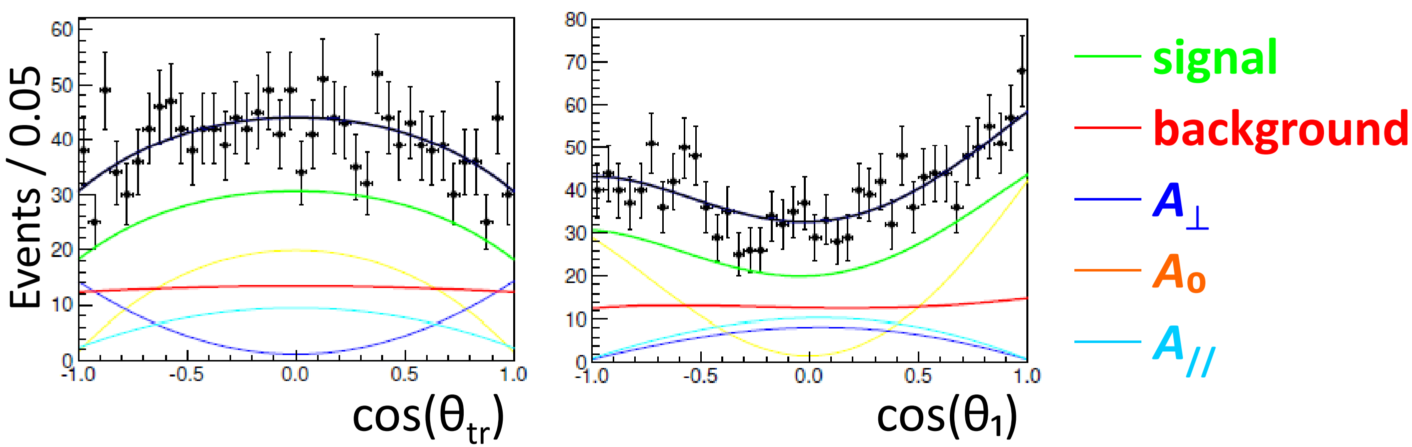
More tracks in the decay final state, larger improvement.

CPV in $B^0 \to D^{*+}D^{*-}$

- **Angular analysis is needed to access the CPV in the *P→VV* decay**
  - Distributions of θ_{tr} and θ_1 give polarization amplitude ratios, R_0 and $R_\perp$.
  - We determine *S*, *A*, R_0, and $R_\perp$ simultaneously by a fit to 5-dimensional (Δt, $\cos(\theta_{tr})$, $\cos(\theta_1)$, ΔE, M_{bc}) distribution.



MC simulation



MC-simulated $\cos(\theta_{tr})$ and $\cos(\theta_1)$ distributions with input values of R_0=0.55 and $R_\perp$=0.16 together with fitted curves.

CPV in $B^0 \to D^{*+}D^{*-}$ *New!*

- **Fit result of S, A, R_0, and $R_\perp$**

$$S = -0.79 \pm 0.13 \pm 0.03$$

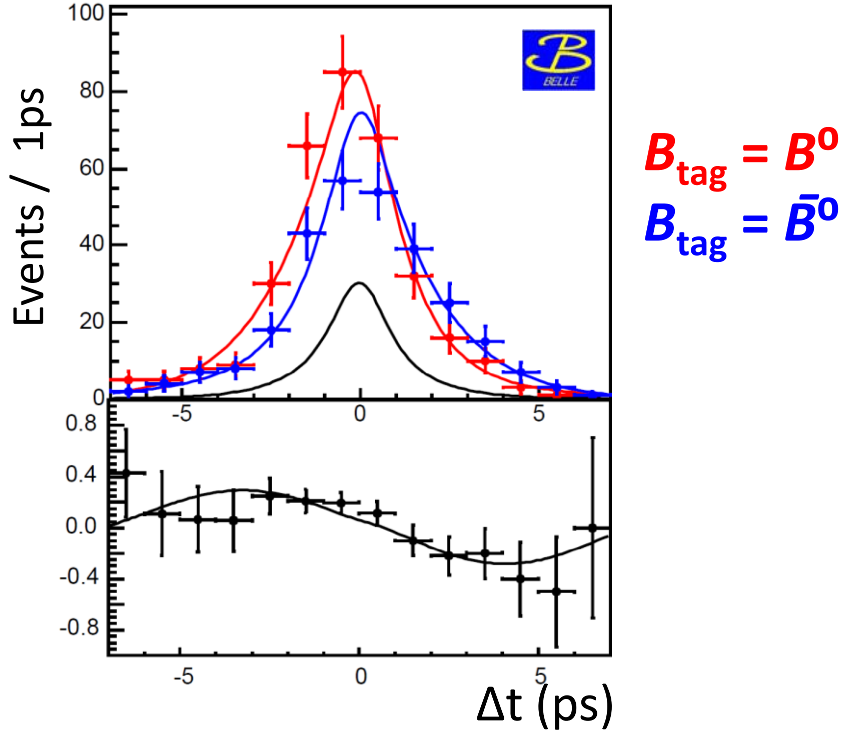
$$A = +0.15 \pm 0.08 \pm 0.02$$

$$R_0 = 0.62 \pm 0.03 \pm 0.01$$

$$R_\perp = 0.14 \pm 0.02 \pm 0.01$$

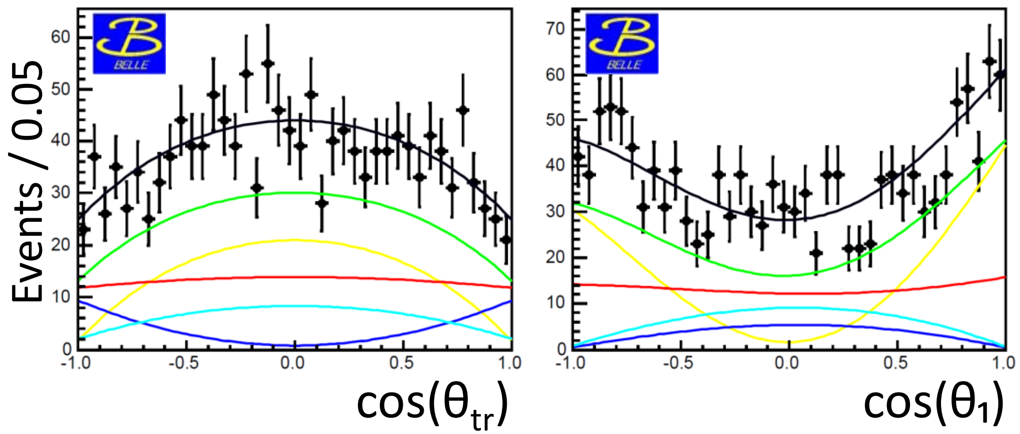
772 x 10^6 $B\bar{B}$ pairs

Belle preliminary



Sources of systematic errors

Category	δS	δA	$\delta(R_0)$	$\delta(R_\perp)$
Vertexing	±0.019	±0.021	±0.004	±0.004
Flavor tagging	±0.004	±0.003	< 0.001	< 0.001
Vertex resolution	±0.020	±0.004	±0.001	±0.001
Physics parameters	±0.004	±0.001	±0.001	< 0.001
Fit model	±0.002	< 0.001	±0.005	±0.002
Tag-side interference	±0.001	±0.008	< 0.001	< 0.001
Polarization recon. eff.	< 0.001	< 0.001	±0.002	±0.001
Total	±0.028	±0.023	±0.007	±0.005



Manifestation of *CPT* Violation

- ***CPT*-violating complex parameter: *z***
  - **Re(*z*) ≠ 0 and/or Im(*z*) ≠ 0 ⇔ The *CPT* is violated.**

- **The Δ*t* distribution function with *CP* and *CPT* violation**

Applicable for any neutral B decay.

$$P(\Delta t, q; z) = \frac{\Gamma_d}{2} e^{-\Gamma_d|\Delta t|}\left[\frac{|\eta_+|^2 + |\eta_-|^2}{2}\cosh\frac{\Delta\Gamma_d}{2}\Delta t - \mathrm{Re}(\eta_+\eta_-^*)\sinh\frac{\Delta\Gamma_d}{2}\Delta t + \frac{|\eta_+|^2 - |\eta_-|^2}{2}\cos\Delta m_d\Delta t - \mathrm{Im}(\eta_+\eta_-^*)\sin\Delta m_d\Delta t\right]$$

$$\eta_+ \equiv A_1\overline{A}_2 - \overline{A}_1 A_2,$$

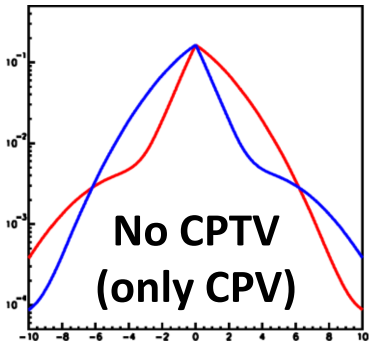
$$\eta_- \equiv \sqrt{1-z^2}\left(\frac{p}{q}A_1A_2 - \frac{q}{p}\overline{A}_1\overline{A}_2\right)$$

$$A_1 \equiv \langle f_1|H_d|B^0\rangle, \quad \overline{A}_1 \equiv \langle f_1|H_d|\overline{B}^0\rangle,$$

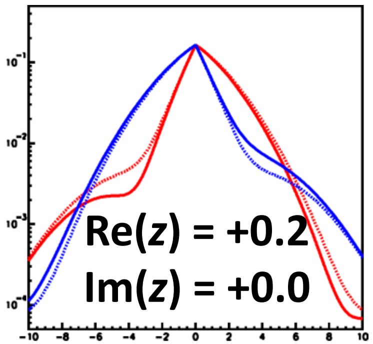
$$A_2 \equiv \langle f_2|H_d|B^0\rangle, \quad \overline{A}_2 \equiv \langle f_2|H_d|\overline{B}^0\rangle,$$

The $q = \pm 1$ is taken into account of the *A*.

Example of *CPT*-violated Δ*t* distribution in $B^0 \to J/\psi K_S^0$



If *CPT* is violated



$B_{tag} = B^0$

$B_{tag} = \overline{B}^0$

Determination of the CPTV Parameters

- *B* meson candidates in 535×10^6 $B\bar{B}$ pairs

Decay modes (event counts)	Sensitivity
$J/\psi K_S^0$(7,713), $J/\psi K_L^0$(10,966)	Mainly to Re(*z*) and $\Delta\Gamma_d/\Gamma_d$
$D^-\pi^+$(39,366), $D^{*-}\pi^+$(46,292), $D^{*-}\rho^+$(45,913)	Mainly to Im(*z*)
$D^{*-}\ell^+\nu_\ell$(383,818)	
$D^0\pi^+$(216,605), $J/\psi K^+$(32,150)	Only to Δt resolution

- Unbinned maximum likelihood fit

# of free parameters

Main physics parameters	3
Other physics parameters	5
Δt resolution function	34
Wrong tagging probabilities	24
$D^{*-}\ell^+\nu_\ell$ background model	6

… Re(*z*), Im(*z*), $\Delta\Gamma_d/\Gamma_d$ (CPTV)

… $|\lambda_{CP}|$, $\arg(\eta_{CP}\lambda_{CP})$, Δm_d, τ_{B^0}, τ_{B^+}

Two individual sets depending on configuration of the silicon vertex detector

CPTV in B^0 Decays *New!*

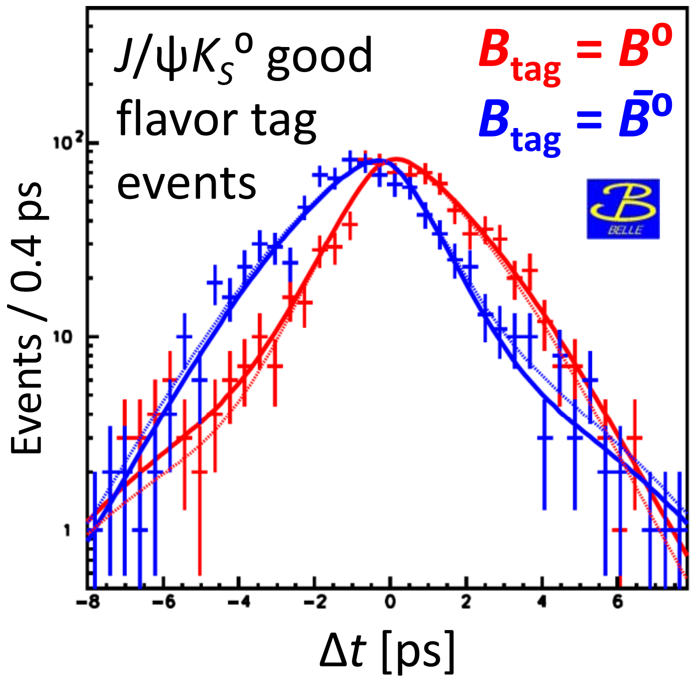
Belle preliminary

$$\mathrm{Re}(z) = (+1.9 \pm 3.7 \pm 3.2) \times 10^{-2}$$

$$\mathrm{Im}(z) = (-5.7 \pm 3.3 \pm 6.0) \times 10^{-3}$$

$$\Delta\Gamma_d / \Gamma_d = (-1.7 \pm 1.8 \pm 1.1) \times 10^{-2}$$

535 x 10^6 $B\bar{B}$ pairs



Light lines indicate Re(z) = +0.2 Im(z) = +0.0 case.

Other parameters

$$\tau_{B^0} = 1.531 \pm 0.004 \quad \text{(ps)}$$

$$\tau_{B^+} = 1.639 \pm 0.006 \quad \text{(ps)}$$

$$\Delta m_d = 0.506 \pm 0.003 \quad (\text{ps}^{-1})$$

$$|\lambda_{CP}| = 0.999 \pm 0.004$$

$$\arg(\eta_{CP}\lambda_{CP}) = -0.70 \pm 0.04$$

Above λ_{CP} corresponds to S = +0.645, which matches Belle's latest result, $S = +0.668 \pm 0.023 \pm 0.012$.

Sources of systematic errors

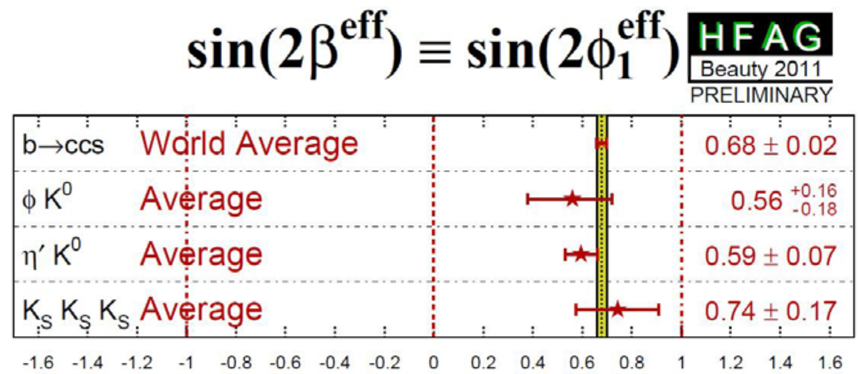
Category	$\delta(\mathcal{R}e(z))$	$\delta(\mathcal{I}m(z))$	$\delta(\Delta\Gamma_d/\Gamma_d)$
Vertexing	$+0.005 \quad -0.009$	± 0.006	$+0.006 \quad -0.009$
Vertex resolution	$+0.001 \quad -0.003$	< 0.001	$+0.002 \quad -0.001$
Fit bias	± 0.012	± 0.001	± 0.005
Signal fraction	± 0.004	< 0.001	± 0.001
Background Δt	$+0.003 \quad -0.005$	< 0.001	± 0.002
Tag-side interference	$+0.000 \quad -0.027$	$+0.000 \quad -0.001$	$+0.001 \quad -0.000$
DCS decay	$+0.004 \quad -0.002$	± 0.001	$+0.003 \quad -0.002$
Others	$+0.000 \quad -0.001$	< 0.001	$+0.000 \quad -0.002$
Total	$+0.015 \quad -0.032$	± 0.006	$+0.009 \quad -0.011$

Toward SuperKEKB / Belle II

- **We are to start SuperKEKB from 2014.**
  - x40 luminosity accelerator ($8 \times 10^{35}/cm^2s$), SuperKEKB.
  - More hermetic, granular, and faster signal detector, Belle II.
  - The final integrated luminosity will be $50 ab^{-1}$.

- **We hunt for new physics at the luminosity-frontier.**
  - So far we have found several hints of NP.
  - These hints will be investigated further at SuperKEKB/Belle II.

Present status



Future prospects of Belle II

Mode	$5\ ab^{-1}$		$50\ ab^{-1}$	
	δS	δA	δS	δA
$B^0 \to \phi K^0_S$	0.073	0.049	0.029	0.018
$B^0 \to \eta' K^0_S$	0.038	0.026	0.020	0.012
$B^0 \to K^0_S K^0_S K^0_S$	0.105	0.067	0.037	0.024

Summary

- **We have reported very recent results related to the *CP*- and *CPT*-violating parameter measurements at Belle.**

Belle preliminary

CP violation	$B^0 \to (cc)K^0$	$\sin 2\phi_1 = +0.668 \pm 0.023 \pm 0.013$
		$A = +0.007 \pm 0.016 \pm 0.013$
	$B^0 \to D^+D^-$	$S = -1.06 \pm 0.21 \pm 0.07$
		$A = +0.43 \pm 0.17 \pm 0.04$
	$B^0 \to D^{*+}D^{*-}$	$S = -0.79 \pm 0.13 \pm 0.03$
		$A = +0.15 \pm 0.08 \pm 0.02$
CPT violation		$\mathrm{Re}(z) = (+1.9 \pm 3.7 \pm 3.2) \times 10^{-2}$
		$\mathrm{Im}(z) = (-5.7 \pm 3.3 \pm 6.0) \times 10^{-3}$
		$\Delta\Gamma_d/\Gamma_d = (-1.7 \pm 1.8 \pm 1.1) \times 10^{-2}$

Backup Slides

CKM Matrix and Unitarity Triangle

$$V_{\mathrm{CKM}} = \begin{pmatrix} V_{ud} & V_{us} & \underline{\underline{V_{ub}}} \\ V_{cd} & V_{cs} & V_{cb} \\ \underline{\underline{V_{td}}} & V_{ts} & V_{tb} \end{pmatrix} \cong \begin{pmatrix} 1-\lambda^2/2 & \lambda & \underline{\underline{A\lambda^3(\rho - i\eta)}} \\ -\lambda & 1-\lambda^2/2 & A\lambda^2 \\ \underline{\underline{A\lambda^3(1-\rho-i\eta)}} & -A\lambda^2 & 1 \end{pmatrix}$$

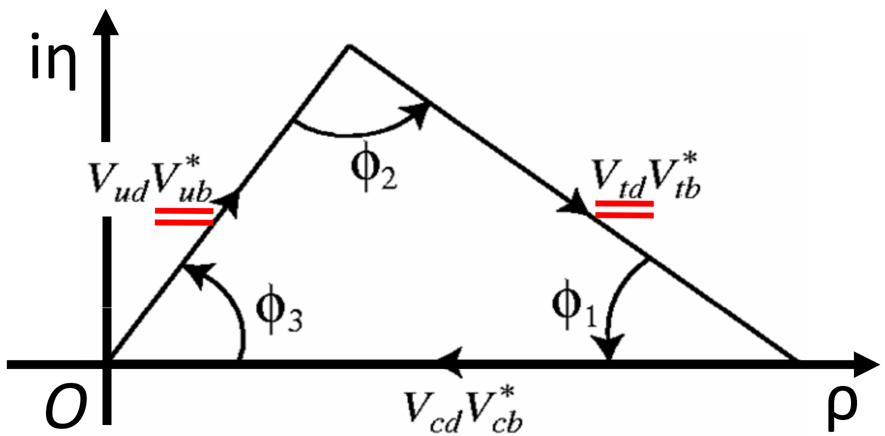
Wolfenstein Parameterization

Irreducible complex phases (in V_{ub} and V_{td} in so called Wolfenstein parameterization) cause the *CP* violation.

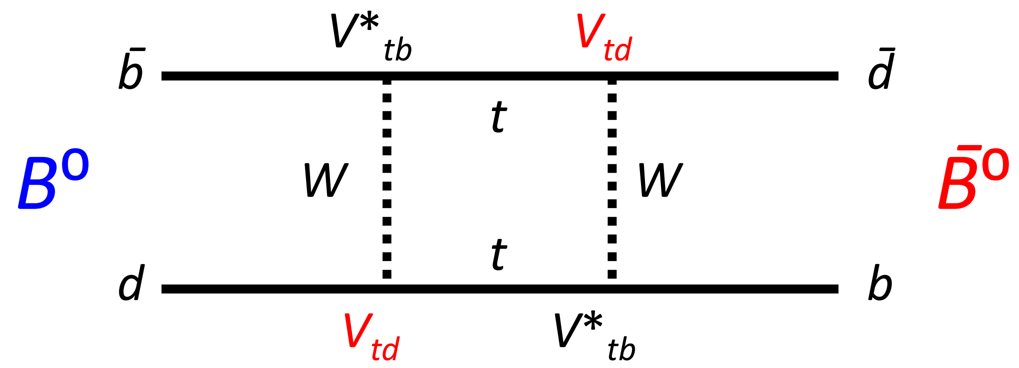
One of the unitarity conditions: $V_{ud}V_{ub}^* + V_{cd}V_{cb}^* + V_{td}V_{tb}^* = 0$

Unitarity condition forms a untarity triangle in the complex plane.

$(\phi_1, \phi_2, \phi_3) = (\beta, \alpha, \gamma)$



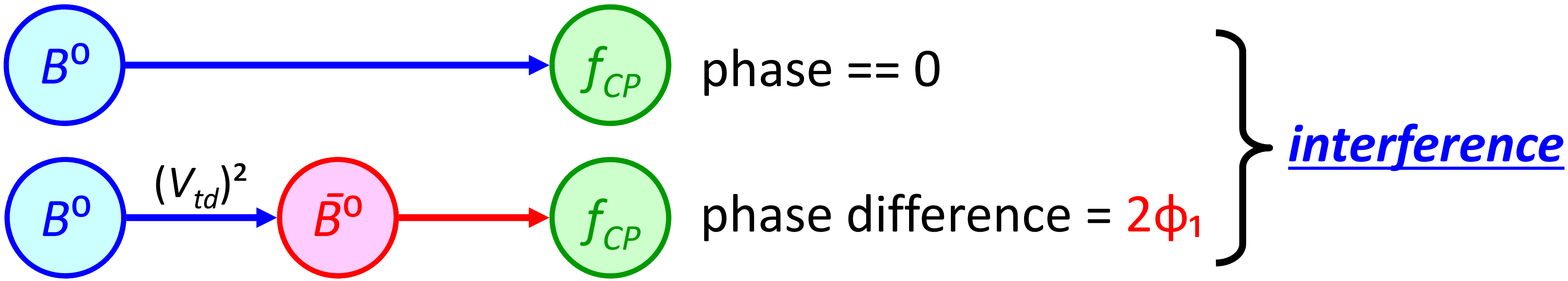
Mixing-Induced *CP* Violation



$\sim (V_{td})^2 \sim e^{2i\phi_1}$

B^0 and $\bar{B}^0$ mix with each other through a box diagram as above.

There is an interference in ($B^0 \rightarrow f_{CP}$) process between a direct ($B^0 \rightarrow f_{CP}$) decay and a decay through the mixing as ($B^0 \rightarrow \bar{B}^0 \rightarrow f_{CP}$).



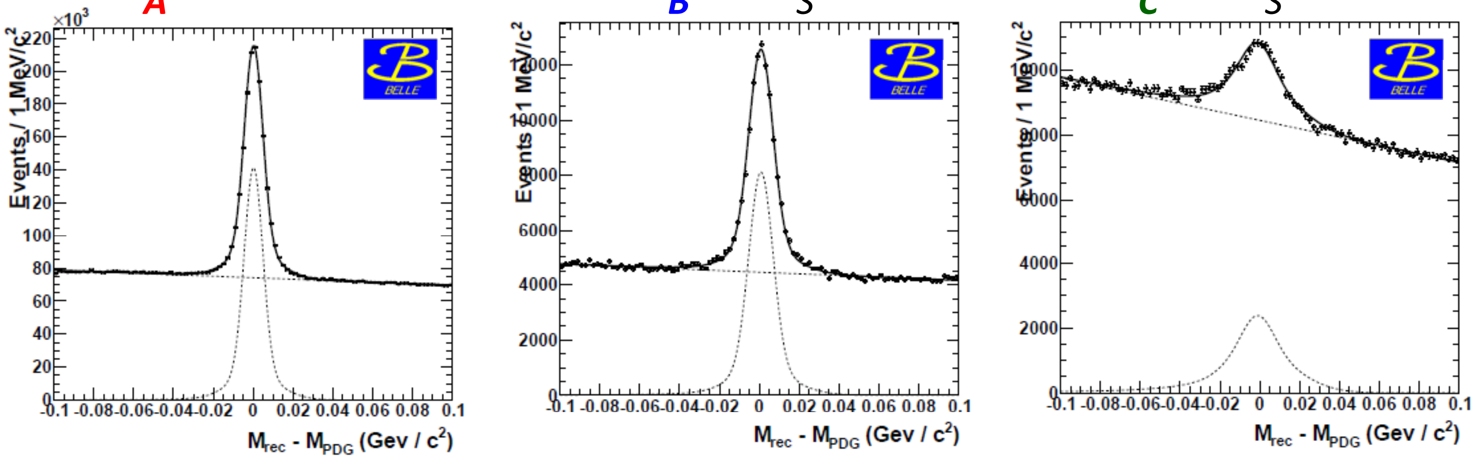
CP violation due to the interference is called “mixing-induced *CP* violation”.

Branching Fraction of $B^0 \to D^+D^-$

- **D^+ reconstruction**
  - D^+ is reconstructed in one of
    $D_A^+ = K^-\pi^+\pi^+$, $D_B^+ = K_S^0\pi^+$, and $D_C^+ = K_S^0\pi^+\pi^0$.

$M_{D^+rec} - M_{D^+PDG}$ distributions

D_A^+ $= K^-\pi^+\pi^+$ | **D_B^+** $= K_S^0\pi^+$ | **D_C^+** $= K_S^0\pi^+\pi^0$



CPT Violation

- **The *CPT* theorem is considered a very strong constraint onto the physics laws.**
- **On the other hand, a *CPT*-violating parameter can be artificially introduced into the standard physics model. We can test the *CPT*-theorem experimentally by measuring the *CPT*-violating parameter.**
- **Thanks to the large *CP*-violation in the *B* meson system, the *CPT*-violation can be expected to manifest itself to the measurable extent if it really exists.**

Mixing-Induced *CPT* Violation

- ***CPT*-violating parameter: *z***

$$|B_L\rangle = p|B^0\rangle + q|\overline{B}^0\rangle \qquad |B_H\rangle = p|B^0\rangle - q|\overline{B}^0\rangle$$

$$\xrightarrow[\text{In } B\bar{B} \text{ mixing}]{CPT \text{ violation}}$$

$$|B_L\rangle = p\sqrt{1-z}|B^0\rangle + q\sqrt{1+z}|\overline{B}^0\rangle \qquad |B_H\rangle = p\sqrt{1+z}|B^0\rangle - q\sqrt{1-z}|\overline{B}^0\rangle$$

Re(*z*) ≠ 0 and/or Im(*z*) ≠ 0 ⇔ The *CPT* is violated.

- **The "golden" Δ*t* distribution function**
  - Applicable for any neutral *B* decays with *CP* and *CPT* violations.

$$P(\Delta t, q; z) = \frac{\Gamma_d}{2} e^{-\Gamma_d|\Delta t|}\left[\frac{|\eta_+|^2 + |\eta_-|^2}{2}\cosh\frac{\Delta\Gamma_d}{2}\Delta t - \mathrm{Re}(\eta_+\eta_-^*)\sinh\frac{\Delta\Gamma_d}{2}\Delta t + \frac{|\eta_+|^2 - |\eta_-|^2}{2}\cos\Delta m_d\Delta t - \mathrm{Im}(\eta_+\eta_-^*)\sin\Delta m_d\Delta t\right]$$

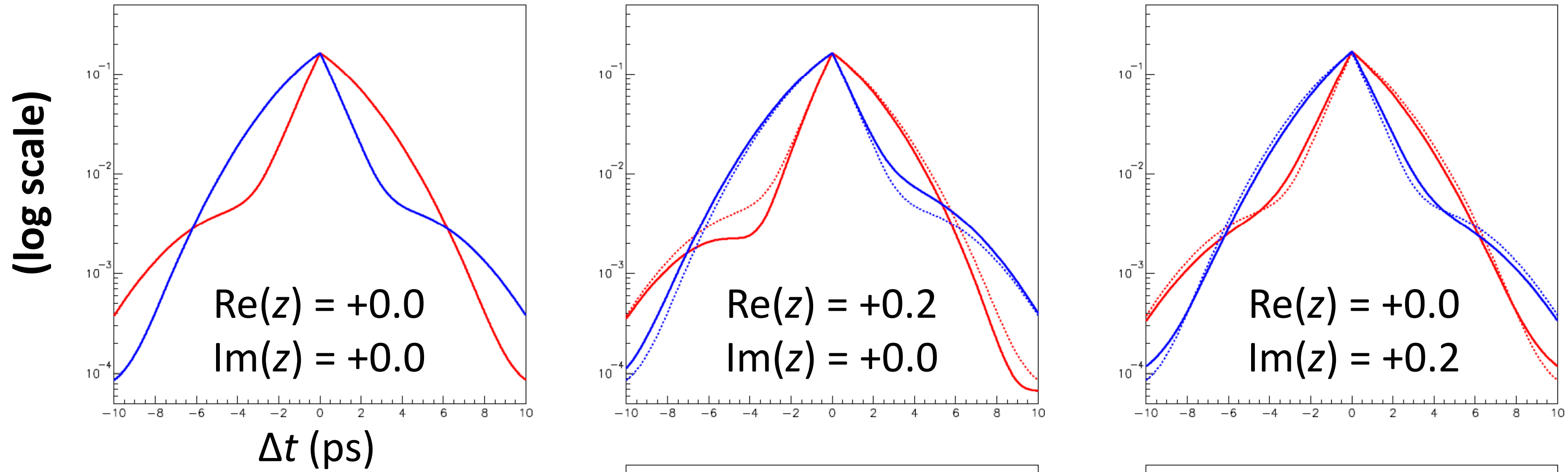
$$\eta_+ \equiv A_1\overline{A}_2 - \overline{A}_1 A_2, \quad \eta_- \equiv \sqrt{1-z^2}\left(\frac{p}{q}A_1A_2 - \frac{q}{p}\overline{A}_1\overline{A}_2\right)$$

$$A_1 \equiv \langle f_1|H_d|B^0\rangle, \quad \overline{A}_1 \equiv \langle f_1|H_d|\overline{B}^0\rangle,$$
$$A_2 \equiv \langle f_2|H_d|B^0\rangle, \quad \overline{A}_2 \equiv \langle f_2|H_d|\overline{B}^0\rangle,$$

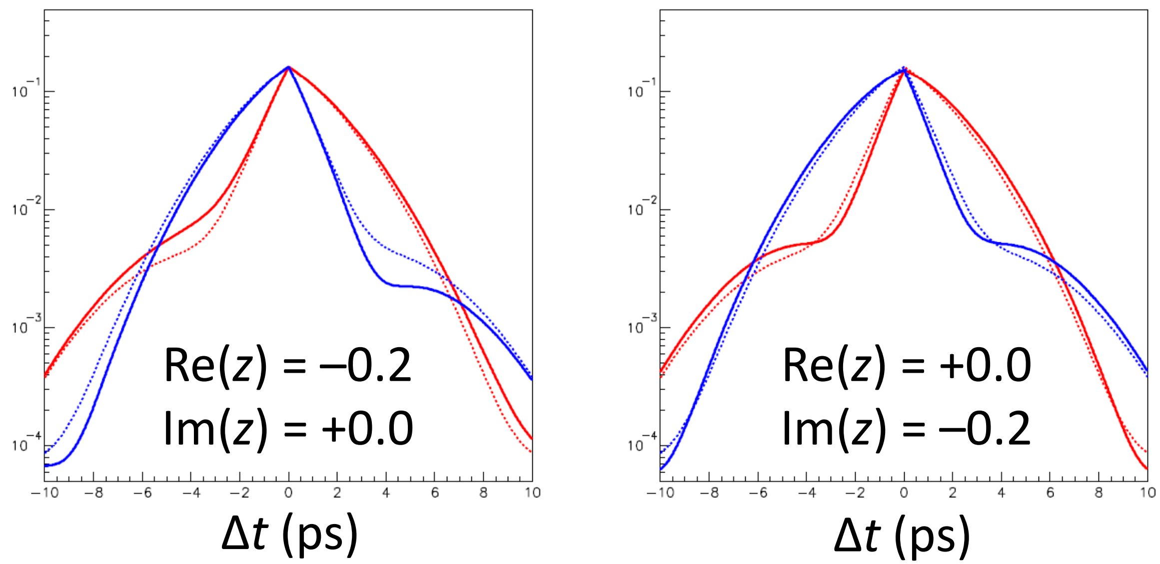
The $q = \pm 1$ is taken into account of the *A*.

Example of the Δt Distributions

- $B_{rec} \rightarrow CP$ eigenstate ($\eta_{CP} = -1$); $B_{tag} \rightarrow$ flavor specific final state



Blue for $q = +1$ ($B_{tag}=B^0$)
Red for $q = -1$ ($B_{tag}=\bar{B}^0$)
Bold solid lines for $z \neq 0$,
thin dashed lines for $z=0$.
‡ $\sin 2\phi_1 = +0.625$



CPTV Measurements at B-Factories

	Decay modes	Amount of data	Results
Belle	Dilepton events	32 fb^{-1}	$\mathrm{Re}(\cos\theta) = 0.00 \pm 0.12 \pm 0.01$ $\mathrm{Im}(\cos\theta) = 0.03 \pm 0.01 \pm 0.03$ $-\cos\theta \equiv z, \quad -\sin\theta \equiv \sqrt{1-z^2}$ N. Hastings *et al.*, Phys. Rev. D**67**, 052004 (2003).
	Hadronic *B* decays	535M $B\bar{B}$	***This talk.***
BaBar	Dilepton events	323M $B\bar{B}$	$\lvert q/p\rvert - 1 = (0.8 \pm 2.7 \pm 1.9) \times 10^{-3}$ $\mathrm{Im}\, z = (-13.9 \pm 7.3 \pm 3.2) \times 10^{-3}$ $\quad \Delta\Gamma \times \mathrm{Re}\, z = (-7.1 \pm 3.9 \pm 2.0) \times 10^{-3}$ B. Aubert *et al.*, Phys. Rev. Lett. **96**, 251802 (2006).
	Hadronic *B* decays	88M $B\bar{B}$	$\lvert q/p\rvert = 1.029 \pm 0.013 \pm 0.011$ $\quad (\mathrm{Re}\,\lambda_{CP}/\lvert\lambda_{CP}\rvert)\,\mathrm{Re}\, z = 0.014 \pm 0.035 \pm 0.034$ $\mathrm{Im}\, z = 0.038 \pm 0.029 \pm 0.025$ $\quad \mathrm{sgn}(\mathrm{Re}\,\lambda_{CP})\,\Delta\Gamma_d/\Gamma_d = -0.008 \pm 0.037 \pm 0.018$ B. Aubert *et al.*, Phys. Rev. Lett. **92**, 181801 (2004).